13

A NOTE ON THE CROSS-SECTION OF THE LUMINOUS DISCHARGE CHANNEL IN A GLOW DISCHARGE

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ABSTRACT. The variation in the cross-section x and the H.W.R. of a luminous discharge channel has been studied for different points in the cathode dark space of a glow discharge in hydrogen and air. Results show that,

(1) the cross-section x reaches a minimum value at some distance Z in front of the cathode,

(2) the value of the minimum cross-section as well as its location in the cathode dark space is a function of the pressure,

(3) both the H.W.R. and x decrease with decreasing pressure for the range 400–252 microns to 100–150 microns. For lower pressures the variation of the two parameters is opposite in character.

INTRODUCTION

In a previous paper (Chiplonkar *et al.*, 1957) it had been shown that significant changes occur, with decrease in pressure, in the cross section as well as the radial intensity distribution of the luminous discharge channel of a glow discharge in air, mostly in the abnormal regime of the discharge. Similar changes were observed when observations were made on the channel at different points in the cathode dark space. At low pressures, when these changes are most pronounced, it was shown that the channel starts with a large cross-section, with a radial distribution of the flat maximum type (observed by Chaudhri and Baqui, 1952) and shows a progressive decrease in the cross-section as it proceeds towards the cathode. At the same time the radial distribution changes into an approximately Guassian form (Chiplonkar, 1940 and 1947; Kamke 1950). These changes are to be expected and are in general agreement with the theory of Kamke. An important observation made by us that there is an increase in the cross-section of the channel in the immediate vicinity of the cathode, suggested a more detailed investigation of this interesting aspect of the problem which it is the object of the present paper to report.

2. EXPERIMENTAL RESULTS

The variation in the radial intensity distribution in the discharge channel was studied as before[1] (Chiplonkar, *et al.*, 1957) at various distances in the

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cathode dark space, extend- ing the observation in some cases to points in the negative glow for discharge in air (voltages 0·68–9·80 KV, pressure 252–52 microns, current = 1·0 mA) and hydrogen (Voltages 0·20–9·83 kV, pressures 400–40 microns, current = 1·0 mA). For the above conditions electrical oscillations were not present he discharge tube.

Following the procedure used previously, the experimental results are discussed with the help of the following parameters.

x = width of the axial region of the channel over which the intensity is constant

Z = distance of the channel from the cathode

d = D.S.L. = length of the cathode dark space

H.W.R. = half width radius for the total radial distribution as measured directly from the microphotometer curves.

A few typical individual observations are given in Tables I–III and Fig. 1, while the final results are presented in Table IV.

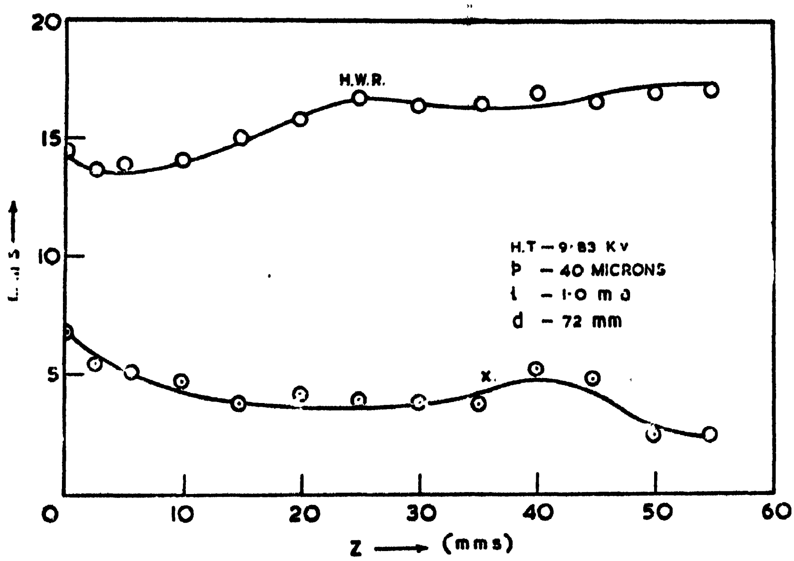

Fig. 1. Variation in the value of x and H.W.R. with Z for discharge in hydrogen.

3. DISCUSSION

The value of x and the half width radius (H.W.R.) can be taken as an adequate measure of the localisation of the discharge channel. An increase in the localisation being equivalent to a decrease in both the cross-section parameter x and the H.W.R. for the distribution. It will be noticed that in the case of all the observations reported here, the cross-section x of the discharge channel attains a minimum value for some point in front of the cathode. The variation of x_0, the value of the cross section at the cathode, and of the minimum value

TABLE I

Discharge in air

$H\text{-}T$ = 6.14 KV,	i = 1.0 mA	p = 53 microns	d = 50 mm
Z(mm)	x(mm)	$H.W.R.$(mm)	
0.0	07.4	16.9	
3.0	05.2	14.1	
8.0	05.1	13.9	
15.0	04.6	14.0	
25.0	04.3	14.6	
30.0	04.1	16.5	
35.0	04.8	16.9	
40.0	04.7	16.8	
45.0	04.7	16.5	
50.0	05.5	17.0*	

TABLE II

Discharge in hydrogen

$H\text{-}T$ = 0.84 KV,	i = 1.0 mA	p = 155 microns	d = 22 mm
Z(mms)	x(mms)	$H.W.R.$(mms)	
0.0	14.0	9.2	
3.0	13.9	14.2	
6.0	13.0	11.1	
9.0	12.0	12.0	
12.0	12.4	16.9	
15.0	12.6	16.8	
18.0	13.2	11.4	
21.0	15.1	13.4	
23.0	17.6	17.0*	

TABEL IV

Discharge in air			At cathode $Z = 0$		At D.S.L. $Z = d$		x_{min} Minimum value of x (mm)	Position of x_{min}(mm.)	Minimum value of H.W.R.(mm.)	Position of H.W.R. min. (mm).
HT(KV)	p(microns)	d(mm)	x_0(mm)	(H.W.R.) (mm)	x_d(mm)	(H.W.R.)$_d$ (mm)				
0.68	205	10	26.2	16.4	~ 27	16.4	20.0	6.0	15.9	3.0
1.18	100	18	15.8	10.7	~ 12	17.0	9.6	14.0	10.6	3.0
1.96	73	30	13.8	—	15.6	17.0	12.0	15.0	12.6	15.0
3.94	58	42	11.0	12.8	~ 10	17.0	7.6	20.0	12.8	0.0
6.14	53	50	7.4	16.9	5.5	17.0	4.1	30.0	13.9	8.0
9.80	52	54	9.8	15.0	—	—	3.9	15.0	15.0	0.0
Discharge in hydrogen										
0.20	400	10	27.1	15.4	17.0	17.0	15.3	6.0	15.4	0.0
0.84	155	22	14.0	9.2	17.6	17.0	12.0	9.0	9.2	0.0
2.03	81	40	10.1	12.8	12.0	17.0	5.7	25.0	11.4	3.0
4.14	57	54	4.6	8.8	4.1	—	2.1	25.0–30.0	6.8	30.0
7.28	45	65	7.6	17.0	—	—	4.1	30.0	12.8	20.0
9.83	40	72	7.2	14.6	—	—	3.9	15.0	13.6	3.0

TABLE III

Discharge in hydrogen

$H.T. = 4.14$ KV $\quad i = 1.0$ mA $\quad p = 57$ microns $\quad d = 54$ mm.

Z(mm)	x(mm)	$H.W.R.$(mm)
0.0	4.6	8.8
3.0	4.0	9.3
6.0	3.9	10.5
10.0	3.6	10.8
15.0	3.5	9.4
20.0	2.7	7.6
25.0	2.1	7.3
30.0	2.1	6.8
35.0	2.5	7.5
40.0	2.7	—
45.0	3.2	—
50.0	3.1	—
55.0	4.1	—

* Radius of the discharge tube $\sim$ 17.0 mm.

of x with pressure in the case of the two cases, shown in Fig. 2, are observed to be quite similar. Both of them show a minimum value for values of $p \sim 50$ microns. That there is a significant change in the state of the discharge at this pressure is indicated by Fig. 3 which shows the variation in the location of the minimum, with the pressure in the discharge tube. In the high pressure region

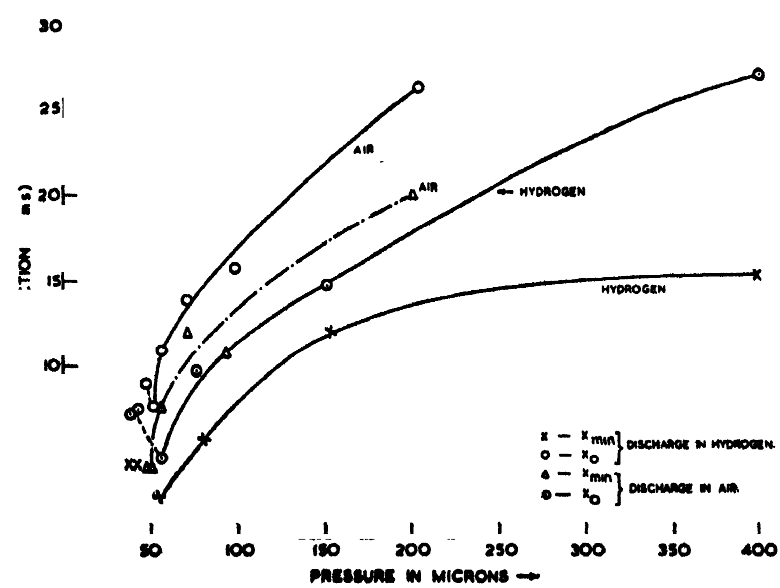

Fig. 2. Variation in the cross-section of discharge channel with pressure for discharge in air and hydrogen.

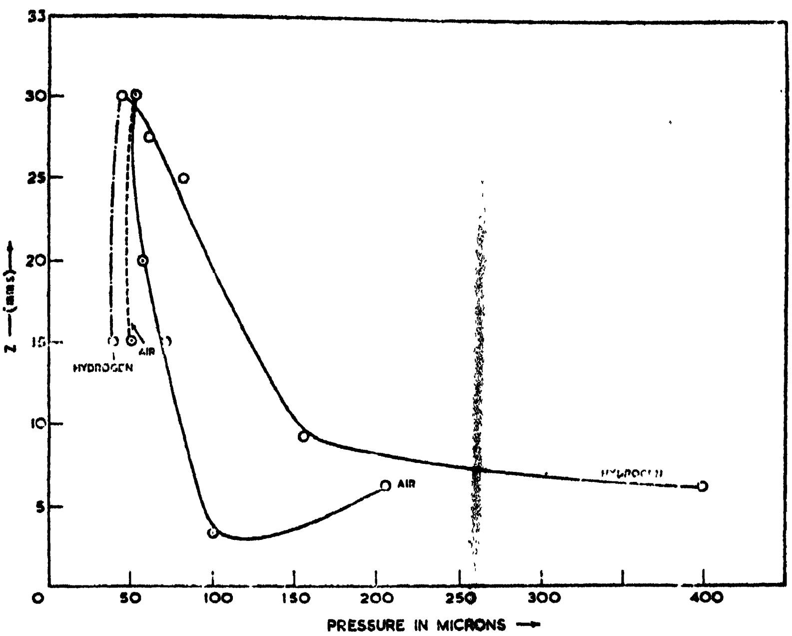

Fig. 3. Variation in the position of x_{min} with pressure for discharge in air and hydrogen.

(400–250 microns to 50 microns) the position of the minimum moves away from the cathode as the pressure is reduced. Its distance from the cathode reaches a maximum value at about this pressure; there are definite indications that it shows a sharp movement towards the cathode for pressures lower than this value.

The gradual constriction of the discharge channel from its origin at the beginning of the cathode dark space towards the cathode, could be explained in terms of the processes visualised in Kamke's theory (Kamke 1950). The increase in the cross-section in the neighbourhood of the cathode and its peculiar dependence on the pressure described above, however, may be taken to indicate the occurrence of a new process (like the photoelectric emission from the cathode) which is independent of the radial distribution of the positive ions coming towards the cathode. The positive ions and/or the fast neutral particles that enter this region have high velocities and therefore are not expected to be sensitive to changes in the nature and the distribution of the space-charge in this region; for although there is a net positive space-charge in the region of the cathode dark space, it is likely that the space-charge becomes electronic in the immediate vicinity of the cathode.

The variation of the H.W.R. with the pressure under the same conditions is shown in Fig. 4. The observations reveal that for the range of pressures (400–250 to 100–150 microns) there is a decrease of the H.W.R. with decreasing pressure, a variation which is similar to the one observed for the x values for these pressures. The variation in the lower pressure range is, however, very peculiar; after reaching a minimum value for $p \sim 100$–150 microns the H.W.R.

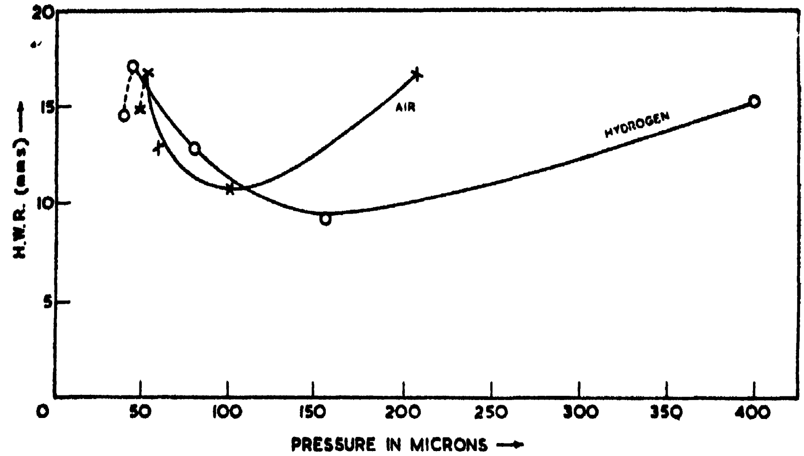

Fig. 4. Variation in the value of H.W.R. (at $Z = 0$) with pressure for discharge in air and hydrogen.

rises to a maximum for $p \sim 50$ microns (the same pressure for which x attains its minimum value) after which there are indications of a sharp fall. The physical significance of this observation does not seem to be clear at this stage.

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